QUANTITY-DISTANCES WASTE BIG BUCKS & CAN BE UNSAFE

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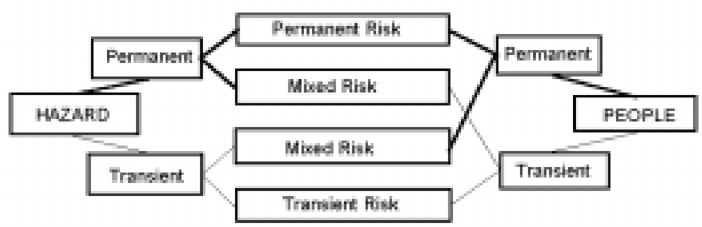
PREFACE

The paper starts with an overview of the primitive risk theory that Q-Ds represent. When a hazard, exposure and people come together a risk exists and Figure 1 shows this.

FIGURE 1 - SIMPLE RISK

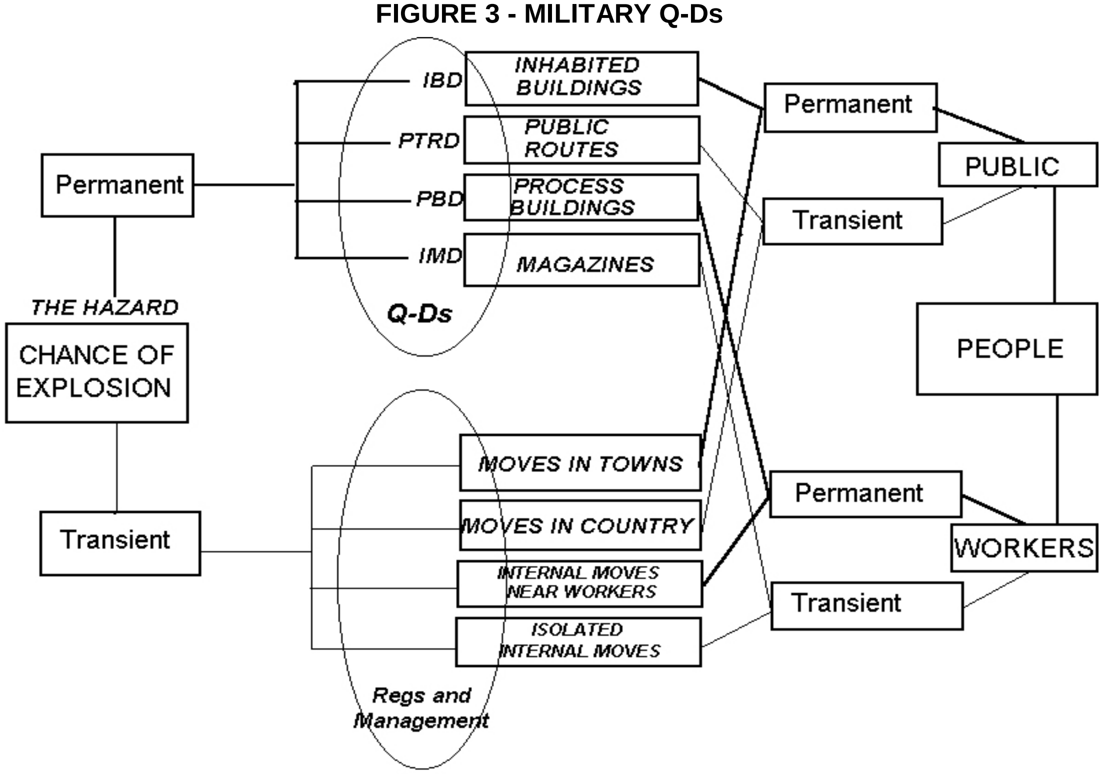
Hazards and people can exist either permanently of transiently. This complicates Figure 1.

FIGURE 2 - NOT SO SIMPLE RISK



Military Quantity-distances (Q-Ds) differentiate between the public and workers essential to explosive handling. Inessential workers are part of the public. Thus the final risk diagram becomes.....

FIGURE 3 - MILITARY Q-Ds



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In other words, *Q-Ds are applied when the public or essential workers are exposed either permanently or transiently to the permanent chance of an explosion*.

The Q-Ds themselves fall into four main categories, Inhabited Building Distances (IBD), Public Transport Route Distances (PTRD), Process Building Distances (PBD) and InterMagazine Distances (IMD), each category representing different levels of consequence deemed acceptable to those who prescribed the Q-Ds.

INTRODUCTION

Within these four Q-D categories there are two indices which determine which Q-D prescription should be selected for use in a given situation. The first is the United Nations' Hazard Division 1 subdivisions of the explosives being considered. The second is the Net Explosive Quantity (NEQ).

These indices are two of the three major reasons why big bucks are wasted. The third reason introduces probabilities. Lets look first at the waste caused by using the two Q-D indices.

WASTE CAUSED BY INDEXING ON UN HD 1 DEFINITIONS

The Purpose of the UN HDs (Not for Q-Ds!)

The UN HD 1 definitions of explosive dangerous goods were designed as safety advice for firemen and others who respond to emergencies with explosive loads in transit. The definitions are based on credible worst case events.

Firemen have a number of other UN HD definitions of dangerous goods to memorise against the chance of meeting them on fire in transit. This memory feat enables them to take instant but sound safety action on the spot.

With fires amongst explosive loads firemen use one or more of three methods to stay safe. They can stand off at a distance, take cover or work from under a water jet. They would put distance between themselves and a load to protect against blast and they would take cover to protect against fragments. To protect against radiated heat they would either take cover or work openly from under a jet of water.

The HD 1.1 definition (mass explosion with projections) indicates to firemen that they should use distance and take cover, which probably they would do until the load exploded and then break cover to deal with new secondary fires. For HD 1.2 (small sporadic explosions with projections) they need only take cover and they might decide to fight the fire from behind close-in cover. For HD 1.3 (mass or sporadic explosive fires with or without projections) they would take action as for HD 1.2 but if after observing the fire for a while they wished to approach it they would do so either with thermal shielding (mobile cover) or under water jets. HD 1.4 explosive fires are not significant hazards but it is useful for firemen to know that denying them atmospheric oxygen won't put them out. Firemen also use the HD 1 definitions to make emergency scenes safe which can be of especial importance in towns.

The definitions also tell firemen of the event duration risks. For instance after an HD 1.1 site has exploded it will no longer be a source of risk so it should be safe to fight any secondary fires caused by projections from the explosion. On the other hand an HD 1.2 site remains a risk until its fire is extinguished or it burns itself out. Firemen could be at risk if they tackle any secondary fires caused by its projections. Firemen consider HD 1.2 to be the greater danger when they are doing their job.

The HD 1 definitions together with the corresponding classifications of explosives have proved in practice to be very effective for firemen when dealing with fires in explosives in transit and in magazines. Together the UN definitions and classifications are excellent for their designed purpose - they are an exemplary use of the KISS principle (keep it short and simple). Firemen have to make split second decisions, they don't have time to consider detailed and complex matters so the hazard definitions have to be as short and as simple as possible without loss of validity. Therefore the number of definitions is an irreducible minimum and what each one says is simplified by assuming credible but extreme worst case effects only. By applying these simplest possible worst case HD 1 definitions firemen have been effective in keeping themselves and others safe in emergencies without loss of precious time.

Regrettably this essential and very effective simplicity works against the cost effectiveness of Q-Ds simply because the HD 1 definitions were never designed as Q-D indices.

Efficient Licensing Needs At Least Ten HD 1 Definitions

For magazine licensing purposes the UN HD 1 definitions were adopted around the world by the military in the 1960s as the keys to licensing prescriptions. They are still used this way. With hindsight it is clear that this ‘worst case explosion’ approach is inappropriate to permanent storage. Regrettably each inappropriate use generates more cost than is necessary for actual safety. Happily this shortcoming is being recognised more and more.

Firemen when responding to emergencies do not consider costs. They have neither the time nor the need to do so. As has already been explained, this lack of time compelled the HD definitions to be simple, minimal and based on worst cases.

On the other hand those planning or managing explosive site operations do like to consider costs and compared to firemen they have plenty of time to do this. A lot of this time could be spent making sites safe as cost effectively as possible except that this is limited by the use of the four HD 1 definitions as keys to orthodox licensing using quantity-distances. Consequently Q-Ds deal with worst cases only and by definition, worst cases seldom apply. This limitation works heavily against cost effectiveness.

For Q-D licensing to be cost effective the number of HD 1 definitions should be increased to cover all foreseen combinations of primary explosion effects and then linked to new Quantity-distance prescriptions. All these explosion effects are explained in great detail in Appendix 1 but it helps the argument to look now at a major example. The UN HD 1.1 definition covers explosion effects from a mass detonation of lots of heavy steel cased ammunition to a mass explosion of black powder in cardboard boxes. This is entirely satisfactory for firemen but no use for cost effective site safety.

The author has ten combinations of primary explosion effects significant to mitigation costs, in other words it seems that there should be at least ten HD 1 definitions for licensing to begin to be cost effective. Other people may have different combinations but all will have many more than the present number of four. The author's ten are at Appendix 2. They are grouped under HD 1 definitions in descending order of mitigation costs.

However, the massive effort involved in remarking packages etc, writing new Q-D prescriptions and getting agreement to them around the world means that this change would be a mammoth task generating huge costs globally so it is unlikely that a new list of HD 1 definitions would ever be adopted.

Consequently although there is no classification of explosives specifically designed for licensing purposes, there is also no realistic expectation of there ever being one.

Happily Explosion Consequence Analysis overcomes this deficiency as HDs and Q-Ds are ignored. Instead the potential primary explosion effects are identified and then related to site circumstances. The resulting combination of primary and secondary effects are mitigated using explosives safety techniques until the consequences meet a site operator's safety requirements.

WASTE CAUSED BY INDEXING ON NEQs

BACKGROUND

When there is an explosion firemen like to know if they should expect another at the same site or not.

UN HD 1.1 (en masse explosion) tells them that there will be only one explosion. It will be the biggest that the site or load can produce but there shouldn't be any more. Once the explosion is over firemen are no longer at risk from another explosion at the same place.

HD 1.2 (continuous sporadic explosions) is a different matter. Once explosions start they won't be very big but they will go on until the fire ends. Firemen could be at risk for a long time as fires typically last some hours. A few fires have lasted days.

HD 1.3 (en masse or continuous sporadic burns) is not such a risk. The main threat is radiant heat but there may also be some projections. If there has been a mass fire there will either be no more explosive burning or there could be an aftermath of continuous sporadic but smaller fires of burning explosive.

When a national authority classifies an explosive as HD 1.1, they are telling firemen that it will all be consumed in one big bang. Thus when the classification also says what size the net explosive content (NEC) is of an item, they are saying that it will all be consumed in that big bang, there should be nothing left after the explosion to be a major worry.

THE HD 1.1 Q-D ANOMALIES

The Propellant Anomaly

For a lot of military HD 1.1 items their total NEC includes the propellant necessary to deliver the high explosive at its target. For gun ammunition and guided missiles the propellant is around 80% of the total. A classification authority could be obliged to say that all the explosive content would be consumed in one big explosion so the HD 1.1 NEC is given as all the explosive content, be it high explosive or propellant. To do otherwise could be unfair to firemen.

Most modern propellants are designed to not detonate. There are a few exceptions as some propellants are very energetic because they have a lot to do, but for much of the military armoury the propellants have not detonated in accident scenario tests performed as part of weapon acceptance procedures. This inability to detonate can also be deduced from an examination of the chemical compositions, the weapon configurations, the weapon roles and the methods of functioning.

Of course the propellant would be ‘consumed’ in mass explosions but it would not have detonated.

Licensing is based on Net Explosive Quantity (NEQ) which is defined as NEC x Q where Q is the quantity of ammunition of that NEC. A site's NEQ is the total of all the NEQs for all the different types of ammunition on that site. The HD 1.1 Q-Ds are essentially a collection of relationships which determine the distances at which prescribed peak blast shock wave side-on overpressures (Ps) are attained.

For instance in UK, the side-on blast overpressure (Ps) for the prescribed distance to permanent public sites is 5kPa or 3/4 psi. An NEQ of 10,000kg needs a distance of 500m to the public. But supposing that only 20% of this 10,000kg is high explosive then the blast shock wave would be driven by only 2,000kg and this would require the explosives to be only 295m away from the public.

Conversely if the distance to the public is set at 500m then the explosive site could hold five times more high explosive without jeopardising existing safety standards.

Many military HD 1.1 explosive sites are blighted by the presence of non detonating propellants classified as part of the various NECs and included in licensing calculations.

The Black Powder Anomaly

Black powder and its derivatives are sometimes classed as HD 1.1. Whether black powder actually attracts this classification or not will depend on how it is packed but sometimes it finishes up as HD 1.1 because the classification authority has judged that it would all be consumed in one single mass event.

This creates situations when sites holding black powder are licensed according to the HD 1.1 quantity-distances and this can be anomalous as these distances are based on the power of detonating shock waves and black powder doesn't detonate. Of course black powder is very powerful when it burns inside heavy confinement. The result is a loud mass explosion which destroys the confining structure throwing debris a short distance. There may even be a small shock wave created but never one large enough to justify the distances prescribed by the HD 1.1 quantity-distance prescriptions.

However black powder is not normally stored in a confining structure as this greatly enhances its potential for danger, it would be foolish to do this. Instead it is found in light magazines etc with plenty of designed venting thus avoiding a forced violent venting of the structure as described above. Nevertheless it still attracts a quantity-distance as if it were detonable high explosive.

This black powder anomaly can also blight sites.

The Amount Exploding Anomaly and the benefits of Unitisation

Another form of blight is the assumption that all the HE content of a magazine will actually detonate whereas investigations into accidental mass explosions show that this is never the case. There is always

some ammunition thrown out without exploding. The difficulty is predicting how much will not be involved in the mass event. This prediction becomes impossible for large magazines which hold a constantly changing variety of items in large stacks with only gangways between them.

However it becomes manageable when the items involved are in stacks kept apart by unitisation barricades with stack contents under itemised control. The largest explosion can then be engineered to be a unitised stack quantity only and an assessment of the actual explosive behaviour can be made, i.e. the size of an expected partial detonation. This assessment would remain valid so long as the itemised control system shows that the stack contents have not changed.

Unitisation can reduce a 50 tonne net magazine down to a 5 tonne (say) magazine *with no reduction in actual holdings*. So even if the possibility of a partial detonation exists but it is too difficult to assess, with unitisation at least the theoretical maximum possible single explosion is now 5 and not 50 tonnes.

THE HD 1.2 Q-D ANOMALIES

All the HD 1.2 Q-Ds rely on distances which define either the intolerable accumulated fragment density range or the maximum potentially hazardous range. Both these criteria assume that the fragments have come from a detonation. It is a very rare HD 1.2 event indeed that involves a detonation, they are nearly always ‘cook-offs’ which create fewer fragments of much less energy and range.

The other thing these Q-Ds are based on is the assumption that all the stock will react and it never does. Once a round in a stack ‘cooks-off’ or detonates it throws other ammunition clear of the fire.

This weakness in the present HD 1.2 Q-Ds is generally well understood and some new Q-Ds are about to be announced which will more closely resemble reality. However, just like the HD 1.1 Q-Ds they will mostly be derived from HE filled munitions and an examination of Royal Navy stock shows that only about 20% of it is filled with HE so perhaps about 80% of the HD 1.2 stock will still be blighting sites.

THE HD 1.3 Q-D ANOMALIES

The present Q-Ds are highly pessimistic and are still based on a first approximation made around 1960 which relied on the translation of the physics of heat radiated from high temperature nuclear flash sources to the lower temperature regime of heat radiated by explosive fires. This whole anomaly is presented at this Seminar in another paper entitled, “Developing New HD 1.3 Q-Ds” .

Suffice to say that all HD 1.3 explosives when packed as supplied can only burn sporadically, box by box or pack by pack so the heat radiated at any one time is never large enough to warrant a safe distance of more than 10m.

DISCUSSION

The lesson here is that Explosion Consequence Analysis at a very detailed level specific to the circumstances of a particular site will almost always show that the consequences are nowhere near so worrying as the Q-Ds indicate. In fact the results from detailed assessments are always less costly to address than having to shape a site to suit a Q-D prescription.

Having used this analytical technique to determine what the consequences could be, the actual villainous explosion effects which cause the consequences are identified and quantified. Their mitigation down to chosen acceptable levels then becomes an obvious and easy next step.

One of the joys of Explosion Consequence Analysis is that it is a continuously improving technique. Models of explosion effects and their consequences for people, buildings and other explosives are constantly emerging. Unlike the application of Q-Ds it does not encourage stagnation, it permits the immediate application of new and valid science as soon as it is published. It can immediately exploit any emerging, valid knowledge. It is always as close to reality as current science can get and it is getting closer all the time.

WASTE CAUSED BY IGNORING EXPLOSIVE REACTION PROBABILITIES

The ignoring of Explosive Reaction Probabilities is the third way that causes Q-Ds to waste big bucks besides the use of NEQs and UN HD 1 definitions as Q-D indices. There are many ways in which explosives can react when stimulated and often, when the stimulus is accidental, the reaction is much kinder than when stimulated as designed.

It is this very phenomenon that defines the concept of insensitive munitions. In my experience many traditional munitions are already insensitive according to the NATO Insensitive Munitions Information Centre definition.

However the trouble is that the Q-Ds don’t recognise this, they always assume extreme worst cases. For instance HD 1.1 Q-Ds always assume a detonation whereas many modern HE fillings will just deflagrate or burn in a fire depending on a munition’s configuration, so if a risk assessment shows that a fire is the most likely accidental stimulus then the HD 1.1 Q-Ds become technically inapplicable and either a radiant heat model should be used or some protection needs to be provided against low speed projections or both. Often this means that what was thought of an HD 1.1 munition behaves no worse than HD 1.4 in an accident scenario, depending a lot on a particular site’s circumstances, the specific nature of the explosives concerned and site mitigation measures.

This means that assessments of the probabilities of death from an explosion which take account of neither the various Explosive Reactions that could occur nor the probability of each one occurring will also be unrealistically pessimistic and this always involves unnecessary costs.

In other words the adoption of a risk assessment technique that assumes that HD 1.1 explosives always detonate en masse will also waste big bucks.

Q-DS CAN BE UNSAFE

The Obvious Reason

Many military HD 1.1 explosives are HE filled munitions with heavy steel cases. The primary fragments from these can kill people up to an extreme range of around 2km ($1^1/_4$ miles). Given an explosion, the potentially lethal fragment density in most cases will mean that the chance of killing someone beyond the safe blast distance as prescribed by the Q-Ds will probably be less than 1% but this cannot be guaranteed. If these munitions were in igloo magazines or similar then few if any primary fragments could escape; the hazard they represent would disappear. Many Q-D prescriptions do not distinguish between igloos and the more traditional HD 1.1 magazines on the basis of fragment hazard, they only differentiate on the basis of released blast power.

The Legal Reason

In UK and perhaps in other Nations also, the site operator is responsible in law for the safety of a site. Within the military the Q-Ds are prescribed by an authority senior to a site operator on the basis that the blame and liability for any casualties or damage caused by an explosion will be acknowledged and met by that senior authority rather than the site operator provided that the operator has complied with the authority's Q-D prescription.

This legal position is starting to change. The change started in 1974 when the UK Health & Safety At Work Act became law. It requires site operators to be 'safe as far as is reasonably practicable'. Therefore if it was reasonable to place heavy fragmenting HD 1.1 munitions in igloos but they were placed elsewhere because this was permitted by the Q-D prescription and the place elsewhere then exploded killing people through fragment attack, then a Court will be likely to rule that the situation was unsafe.

THE AVOIDANCE OF ALL Q-D ANOMALIES

The Problem

Obviously the Q-D anomalies can be avoided by not using Q-Ds. This statement can be extended by saying that all explosive site operation safety anomalies can be avoided by abandoning any form of prescribed or commanded rules. There is even a debate that the issuing of safety goals by a central authority should be avoided also but the arguments on either side are not yet conclusive.

The problem is the control of safety by central command because achieving real safety in detail through general regulation is a paradox. Safety specific to a site and which changes as the site changes (organic safety) is incompatible with general regulation.

A parallel can be drawn here. Consider two types of national economic systems. One is directed from the centre, it is a command economy. The other runs itself and the only role for the centre is the health of the money supply, it is a free market economy. Recently the command economies of the eastern bloc have failed. This paper has shown that commanded explosive site safety is also a failure.

A Solution - The Safety Case

In the European Union and the UK, for all hazardous sites other than explosives this paradox has long been understood and a sensible alternative has been in use for some time. It is the *Safety Case* and it is akin to a free market economy - how successful it is up to those who invest in it.

What is it? A short definition is:

> A Safety Case is a document that records the levels of safety achieved on a site. These levels are described in terms of consequences and probabilities. The document is site specific and lives as long as the site is operated. The site operator is obliged to keep it up to date as circumstances change on site. The site operator is also obliged to keep trying to lower the consequences and the probabilities. The document is audited periodically to check that it is accurate and that the consequences and probabilities are less than they were at the last audit. It must be demonstrated at all times that all reasonable steps are being taken constantly to improve safety.

A large number of Risk Assessment techniques are employed in the production of a Safety Case.

It is suggested that the Safety Case approach be used for explosive sites also.

For the Safety Case an Explosion Consequence Analysis is used to scope who is at risk. Then some general actuarial data is used for a first estimate of the probabilities of individual and societal fatalities. This is followed by Threat and Hazard Analysis (THA) techniques to determine the likely causes and sizes of actual explosions and the probabilities of the various explosive reactions. The causes can be either under a site operator’s control - internal hazards - or beyond his control - external hazards.

THA is a complex methodology but it is systematic and thorough. As THA work progresses its results modify the initial Explosion Consequence Analysis and Risk Assessments.

The Royal Navy is pioneering Safety Case methodology for explosive sites leading with one which contains both explosives and nuclear facilities. Other papers being presented at this Seminar describe in detail how this methodology is evolving using NIMIC advice as a guide.

APPENDIX 1

PRIMARY EXPLOSION EFFECTS

Explosion effects can be categorised as either primary or secondary. The primary ones are a direct function of an explosive itself and will occur no matter where it explodes. The secondary ones are a function of local characteristics and include ground shock, the rapid growth of pressure in buildings, the projection of building debris, the creation of flame jets, etc, and they are mostly irrelevant to this paper. The relevant primary effects are blast, fragments and radiated heat.

Blast is an effect of detonations. Usually only high explosives detonate with enough power to create any blast of concern. Low explosives, if confined can also produce explosions but the blast in open air is often too little to be a concern. These explosions are confined explosive, rapid fires. As a final twist HE can also burn although detonations cannot always be ruled out when it does so.

For the purposes of this article fragments or Frags fall into two types, those with enough energy to Practically Instantaneously Propagate (PIP) a detonation and those with less energy which can nevertheless still cause casualties. They are abbreviated here as "PIP Frags" and "Cas Frags".

PIP Frags come from military HE shell and bombs which have heavy steel casings. Typically each shell when it detonates gives rise to 5,000 frags of which 1,000 are insignificant dust particles with the rest ranging from hundreds weighing 0.5gm up to a few weighing 100gm or more and all with an initial speed of about Mach 7 or 2,400 metres per second. A PIP frag striking other explosive within about 400m could detonate it. The shorter this distance the more likely it is that the detonation is propagated.

Cas Frags come from either steel packaging not coupled to detonating HE or from steel casings closely coupled to deflagrating HE and low explosives. They are much fewer in number than PIP Frags, typically four per shell, and far heavier. Initial speeds are 100-400 metres per second. They are energetic but not energetic enough to cause PIP.

Radiated Heat is of interest when the explosive events are unconfined or lightly confined en masse fires but only when PIP Frags, Cas Frags and detonations are ruled out.

Blast can be mitigated using distance, blast suppression methods, reduction of explosive weight either simply or through 'unitisation', or any combination of these. Simple reduction of weight costs nothing if it suits owners. The cost of reducing explosive weight through unitisation can be small if sandbag or water barricades are used. The cost of providing distance varies between sites and owners. If the distance is already owned and can be used for something else its running cost attributable to the magazine is nil. If no distance is readily available then acquiring it could be a high capital expense, e.g. buying a farm.

PIP Frags are a major case for mitigation in military depots. Low trajectory PIP frags can propagate detonations across gaps up to almost 400 metres wide, gaps often more than 100 times wide enough to stop propagation by blast attack. These propagations being practically instantaneous are so fast that the blast powers of all the explosions aggregate with distance. Blast aggregation is deeply undesirable and is avoided by barricades alias traverses stopping the PIP frags either at source or at target sites whichever is the cheaper way forward.

On level ground PIP frag trajectories with an elevation greater than 2 degrees have a range of at least 500 metres by which time air drag has taken away all their "PIP sting". Anti-PIP barricades at source should therefore intercept 2 degree frag flight but other angles of elevation should be considered when the ground isn't level.

PIP Frag barricades at source are the most expensive type of barricading. The orthodox double or single slope earthen barricades associated with orthodox licensing prescriptions and of standard 2 degree frag flight intercept design, alias traverses or mounds, can cost more to build than the magazine they surround if earth has to be brought onto site. It pays a site owner to know the worst case PIP frags his specific holdings could generate and have barricades designed to take the "sting" out of just them, plus

20% error margin of course. Cheap materials readily available on site can be utilised, e.g. salvaged wooden railway sleepers. The author has achieved 95% savings with this approach.

PIP frags which skim over the top of a 2 degree barricade or are lobbed won't cause PIP but they can still cause casualties within their range. Beyond barricades and up to about 300 metres away on level ground there is a frag shadow for people standing upright except for lobbed frags. To avoid distant potential casualties from skimming frags high barricades around magazine walls could be needed. To avoid close-in casualties from lobbed frags a barricaded roof could be needed. If both barricades are necessary then earth covered magazines could be the cheapest way forward.

Cas Frags could be left untreated if no potential casualties are foreseen although this doesn't reduce the potential for danger. If treatment is needed the barricades at source are cheaper than those for PIP frags. A simple wall built from standard heavy concrete blocks laid flat might suffice.

Against Radiated Heat the treatment is either distance or thermal shielding. The costs of distance have been discussed above under blast. Thermal shielding can be as cheap as white paint on windows. (N.B. The treatment to protect against the frags of worst case HD 1.3 explosives also acts as a thermal shield.)

APPENDIX 2

TEN IMAGINARY HD 1 DEFINITIONS
DESIGNED FOR MAGAZINE LICENSING PURPOSES

MASS EXPLOSIONS LASTING MILLISECONDS (HD 1.1)

- **Mass detonation with 100% blast and many PIP and Cas Frags**. Mitigation needed for full blast and PIP Frags. (Corresponds to the worst case effects of HD 1.1 and needs the most costly mitigation.)

- **Mass detonation with 100% blast and many Cas frags**. Mitigation needed for full blast plus Cas Frags if frag casualties foreseen.

- **Mass detonation with 100% blast but no significant frags**. Mitigation needed for full blast only.

- **Mass explosion from deflagrating lightly cased or uncased low explosives**. Radiant Heat and possibly some Cas Frags but no blast of significance. Mitigation needed for the Cas Frags else for the radiant heat only.

LONG LASTING EXPLOSIVE EVENTS (HD 1.2) Durations depend on amount of explosive involved and can vary from a few minutes up to two days with a few hours being typical.

- **Sporadic detonations of heavy cased HE.** Minor blast from up to 20kg nett of HE is expected with up to 2kg being typical. Each detonation will create PIP Frags. Lots of unexploded explosives could be projected a few hundred metres. Mitigation needed for PIP Frags and against attrition of the PIP Frag mitigation treatment caused by repeated detonations at the same spot, and for the projected

explosives. (These explosion effects are the basis of the current Q-Ds but they have never been met by the author. They attract the most costly HD 1.2 treatment.)

- **Sporadic deflagrating explosions of heavy cased HE**. Neither detonation nor PIP Frags are expected but they cannot be ruled out. Lots of unexploded explosives could be projected mainly short distances but an occasional long distance is possible if a detonation occurs. Mitigation needed for PIP fragments and for projected explosives but not for spot attrition.

- **Sporadic deflagrating explosions of heavy cased low explosives**. No blast and no PIP Frags but many Cas Frags. Lots of unexploded explosives will be projected short distances. Mitigation needed for Cas Frags and projected explosives.

- **Sporadic deflagrating explosions of uncased or light cased low explosives**. No detonations and no frags. Mitigation needed for projected explosives.

EXPLOSIVE EVENTS LASTING SECONDS (HD 1.3) Massive and fierce fire with neither blast nor fragments. Durations are a function of an explosive's characteristics and typically vary from 6 to 35 seconds. Mitigation of radiant heat needed.

SAFETY CLASS EXPLOSIVES (HD 1.4) Defined as for present HD 1.4.